15 Hz Booster Operation

Eric Prebys

August 12, 2008

Abstract

This note summarizes the work necessary to go to 15 Hz in the Fermilab Proton Source. The hardware limits to the repetition rate will be discussesd, as will the radiation issues associated with the increased beam throughput.

1 Introduction

Recently, there has been much discussion of using the existing Proton Source to drive an intensity-based 8 GeV physics program, to run concurrently with the NOvA experiment in during the next decade. This will require the Booster to run continuously at 15 Hz, with more than twice the present proton throughput.

In discussing the limiting rate of the Proton Source, we must consider two factors: the repetition rate which can by physically sustained by the pulsed elements within the system and the maximum total beam loss, both above and below ground, which is considered acceptable.

In recent years, the beam required from the Booster has increased dramatically, requiring a commensurate increase in average repetition rate. The first formal management of the Booster throughput rate was referred to as the "Proton Plan"[1], a campaign of upgrades undertaken to deliver beam to the MINOS and MiniBooNE neutrino exeriments while still supporting the collider program. Under the Proton Plan, the maximum average Booster repetition rate has been increased from roughly 2.5 Hz to 9 Hz.

2 Rate Limitations

The lattice magnets of the Fermilab Booster operate in an offset resonant circuit at 15 Hz, whether or not beam is present. However, certain elements of the Booster are only pulsed in the presence of beam, and some of these limit the *average* repetition rate to something less than 15 Hz.

In general, under the Proton Plan, if any element of Booster had to be upgraded or replaced to meet 9 Hz goal, the new solution was designed to be compabible with sustained 15 Hz operation.

Thus, at this time, none of the pulsed magnetic elements of the Booster represent any rate limitiation, and the only remaining limits come from the RF system. These are analyzed in some detail in [2], but of particular interest are:

- The end cones of the ferrite-loaded tuners in the 19 Booster RF cavities will overheat at rates in excess of about 10 Hz. These cones have cooling channels, but these will need to be reconnected with the LCW system, and in some cases, leaks will have to be repaired.
- Roughly have of the "bias supplies", which provide the current to modify the resonant frequency of the Booster cavities, have transormers which are inadequate for 15 Hz operation. These supplies will have to be retrofit with more robust transformers.
- The two large anode supplies, which power all of the anodes of the RF power amplifiers, will probably need to be upgraded with more robust transformers.

The details of these upgrades will be described in a separate document, but they are planned to be effected within the scope of normal Proton Source maintenance over the next few years.

3 Radiation issues

The Booster is well short of the passive shielding which would be required for the total proton flux that it accelerators. It is therefore protected by a system of above-ground radiation monitors ("chipmunks"), which are designed to trip the machine off if excessive radiation id detected. In addition, a system of beam loss monitors (BLM's) measure beam loss in the Booster tunnel. These are used to form 100 second running averages, and the Booster is tripped off if any of these exceed pre-determined limits. These limits have been empirically determined to keep the residual activation in the tunnel at a level which will allow hands-on maintenance. Generally, the BLM limits are more stringent than the above-ground limits; that is, excessive beam loss will trip the BLM limit before causing unacceptable radiation above ground.

Historically, these beam lost limits have been the primary limit to total Booster throughput. However, in the past year, Booster efficiency has increase such that the repetition rate limit is hit prior to the radiation loss limit. Typical beam loss at present would allow a maximum proton through put on the order of 1.6×10^{17} protons/hour.

The total proton rate during 15 Hz operation would be 2.2×10^{17} protons/hour, assume 4×10^{12} proton batches. This increased proton throughput should be achieved through the improved Booster corrector system [3], scheduled to be installed in the 2009 shutdown.

4 Summary

The improvements necessary to bring the Booster to the full 15 Hz operation needed by the proposed NOvA-era 8 GeV program should be straightforward, and while there will be challenges, they are

small compared to the improvments which were required to meet the needs of the current neutrino program. For the most part they will be achieved through the remaining elements of the Proton Plan, and through a set of improvements to the Booster RF system which are advisable in terms of overall reliability at any high repetition rate.

References

[1] http://www-accel-proj.fnal.gov/Proton_Plan/index.shtml

[2] R. Ducar and J. Reid, "Booster RF Repetition Rate Limit", FNAL-BEAMS-DOC-2883 (2006)

[3] E.J. Prebys, *et al*,"New Corrector System for the Fermilab Booster", Proceedings of PAC07, Albuquerque, NM (2007)